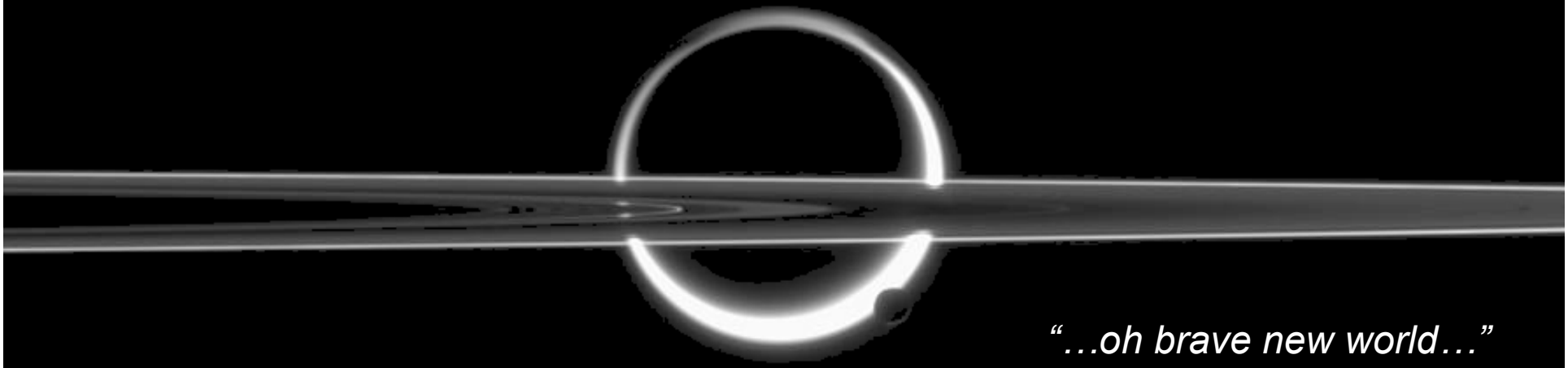
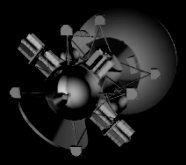
TEMPEST

Titan Exploration and Mapping Plus Enceladus and Saturn Tour
aka Titan Saturn System Mission – TSSM
Science (Jonathan Lunine)



"…oh brave new world…"



Joint Titan-Saturn Science Definition Team

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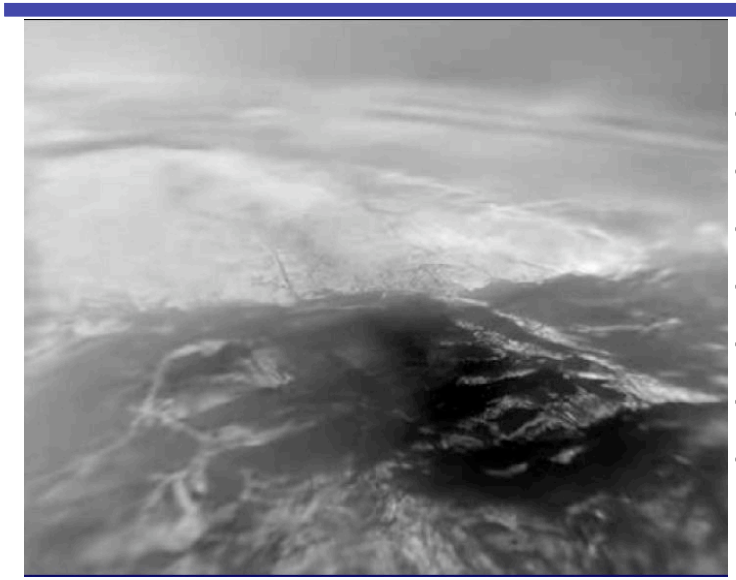
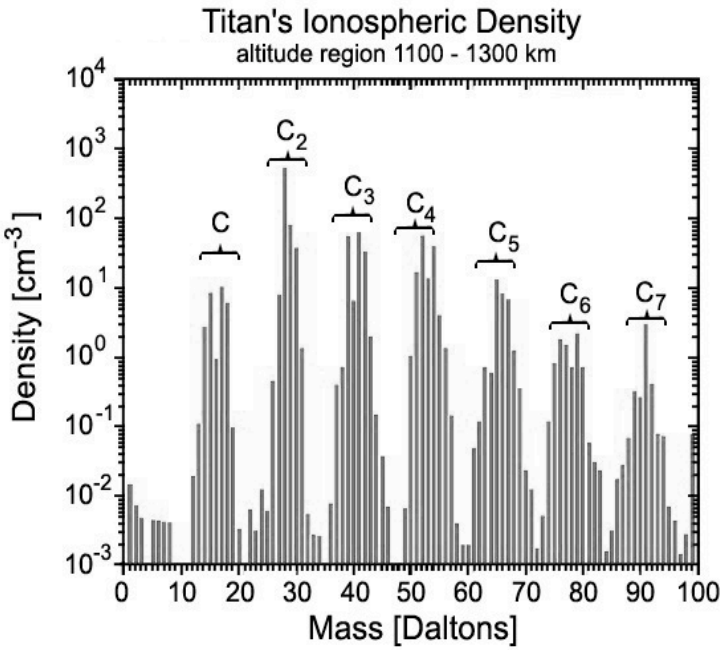
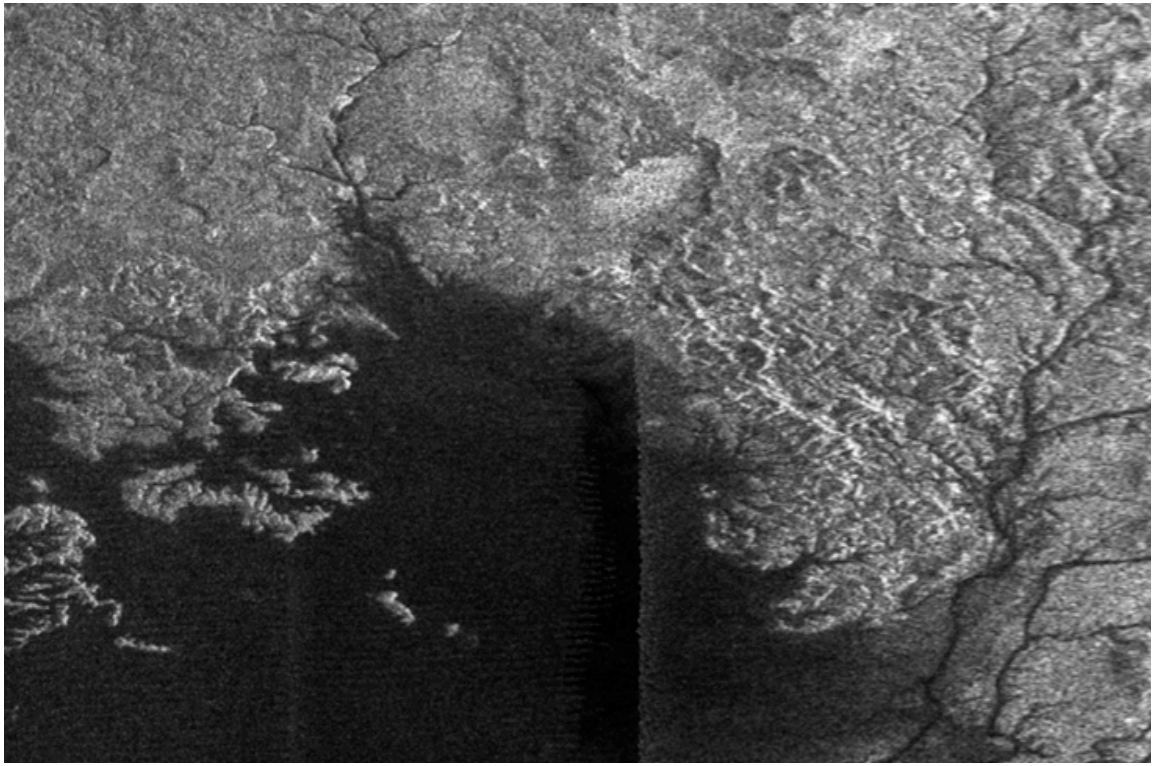
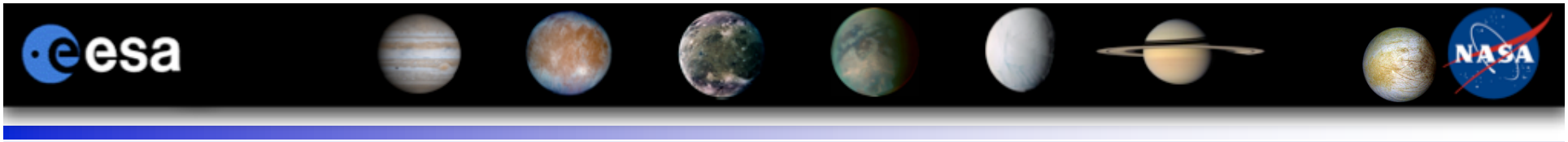
What Cassini-Huygens Did



- Saw methane and ethane clouds that varied
- Imaged fluvial channels, lakes, seas
- Sniffed evaporating methane/ethane from ground
- Found evidence for cryovolcanism
- Detected surface deposits of carbon dioxide
- Detected unexpectedly complex molecules high up
- Measured non-synchronous spin: subsurface ocean?







What we now seek to know

- **Goal A: <u>Titan: an Earth-like System</u>: How does Titan's newly discovered methane hydrological cycle work? What is the interplay among the geology, climatology, hydrology, and long-term evolution of Titan?**

- **Goal B: <u>Titan's Organic Inventory - A Path to Prebiological Molecules</u>: What is the level of complexity of Titan's organic chemistry in the atmosphere, within its lakes, on its surface, and in its putative subsurface water ocean? How does this inventory differ from known abiotic organic material elsewhere in the Solar System?**

- **Goal C: <u>Enceladus and Saturn's magnetosphere</u>: Clues to Titan's origin and evolution. What is Titan's exchange of energy and material with the Saturn magnetosphere and solar wind? What is the extent of chemistry that goes on in the Enceladus geysers and what does it say about the source and the starting materials?**

Goals ---> objectives (long list) -----> measurements (even longer list)

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Science Goals and Objectives

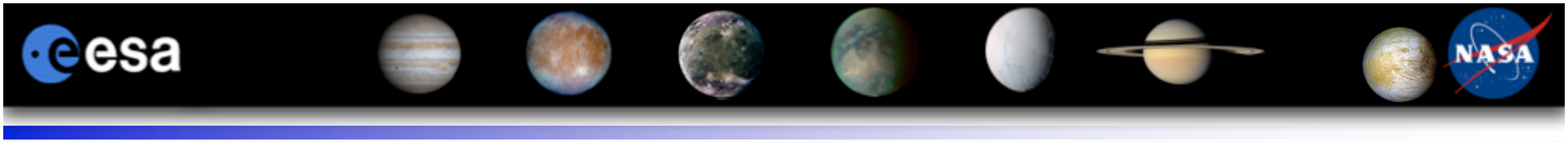
Goals	Objectives
Goal A: Explore Titan and Earth-Like System	Determine the composition and transport of volatiles and condensates in the atmosphere and at the surface, including hydrocarbons and nitriles, on regional and global scales.
	Measure climatological and meteorological variations of temperature, clouds and winds.
	Characterize the relative importance today and throughout time of Titan's geologic, marine and geomorphologic processes e.g. cryovolcanic, aeolian, tectonic, fluvial, hydraulic, impact and erosion.
	Determine how energy is deposited in the upper atmosphere to drive the chemistry and the escape rate of major atmospheric constituents.
	Quantify the atmospheric circulation and flow of energy over seasonal and longer timescales.
	Determine the state of internal differentiation, whether Titan has a metal core and an intrinsic magnetic field, and constrain the crustal expression of thermal evolution of Titan's interior.
	Determine the depth to the subsurface liquid water ocean, its thickness and electrical conductivity, and the lateral variations in thickness and rigidity of the overlying icy crust.
Goal B: Examine Titan's Organic Inventory - A Path to Prebiological Molecules	Determine the chemical pathways leading to formation of complex organics at all altitudes in Titan's atmosphere and their deposition on the surface, including detection and diagnosis of products
	Determine chemical modification of organics on the surface e.g. hydrolysis via impact melt, and assess Titan's potential as a site for pre-biotic chemistry or even exotic forms of life.
	Determine geochemical constraints on bulk composition, the delivery of nitrogen and methane and exchange of surface materials with the interior, including heavy noble gases, isotopic ratios in various organic products, carbon dioxide, and the presence or absence of ammonia.
Goal C: Explore Enceladus and Saturn's magnetosphere - clues to Titan's origin and evolution	Determine how energy is deposited in the upper atmosphere of Titan to drive the chemistry and the escape rate of major atmospheric constituents.
	Determine the time-variability of the Saturnian magnetosphere and its role in escape.
	Infer the internal structure of Enceladus, including the presence of gravity anomalies.
	Determine the composition of Enceladus plumes.
	Understand the formation of surface features on Enceladus, including sites of recent or current activity
	Identify and characterize candidate sites on Enceladus for future in situ exploration.

Titan mission maps to decadal objectives

Decadal Survey p. 138	Cassini	TSSM
What are the chemistry, distribution and cycling of organic materials on Titan?	Methane/ethane sensed at Huygens site; high altitude polymers; lakes, fluvial	High molecular weight mass spectroscopy; hi-res imaging at 5 microns; near-IR spectra
Is Titan internally active, producing water-rich environments with potential habitability?	Spin rate evidence for ocean; radar images of cryovolcanic features; Near-IR spectra of carbon dioxide patches	Accelerometry-enhanced gravity; hi-res surface imaging; surface temperature monitoring in thermal IR; 5-6 micron spectra
What are the current state and the history of Titan's surface?	Radar and VIMS show dearth of craters; fluvial transport at Huygens site	High resolution imaging; radar altimetry and sounding; near-IR spectra
What drives the meteorology of Titan?	Huygens wind and CIRS temperature data provide crude basis for GCM	Sub-millimeter wind/thermal mapping; IR mapping; near-IR cloud sounding
Has there been climate change on Titan?	Fluvial erosion at desert Huygens site; extensive dunes; missing ethane	Hi resolution imaging; radar sounding; near-IR spectra
Could Titan support life forms that do not require liquid water?	High latitude lakes found, as well as environments where active fluvial flow may occur, and cryo-volcanism	Hi-res spectra over 5-6 microns; repeat surface coverage; high molecular weight sampling of upper atmosphere organics

Orbital Planning Payload

- 1-6 micron hi-res imager and spectrometer (HiRIS)
- Radar altimeter and sounder (TiPRA)
- Polymer mass spectrometer (PMS)
- Submillimeter sounder (SMS)
- Thermal infrared radiometer and spectrometer (TIRS)
- Magnetometer and plasma package (MAPP)
- Radio science augmented by accelerometry (RSA)



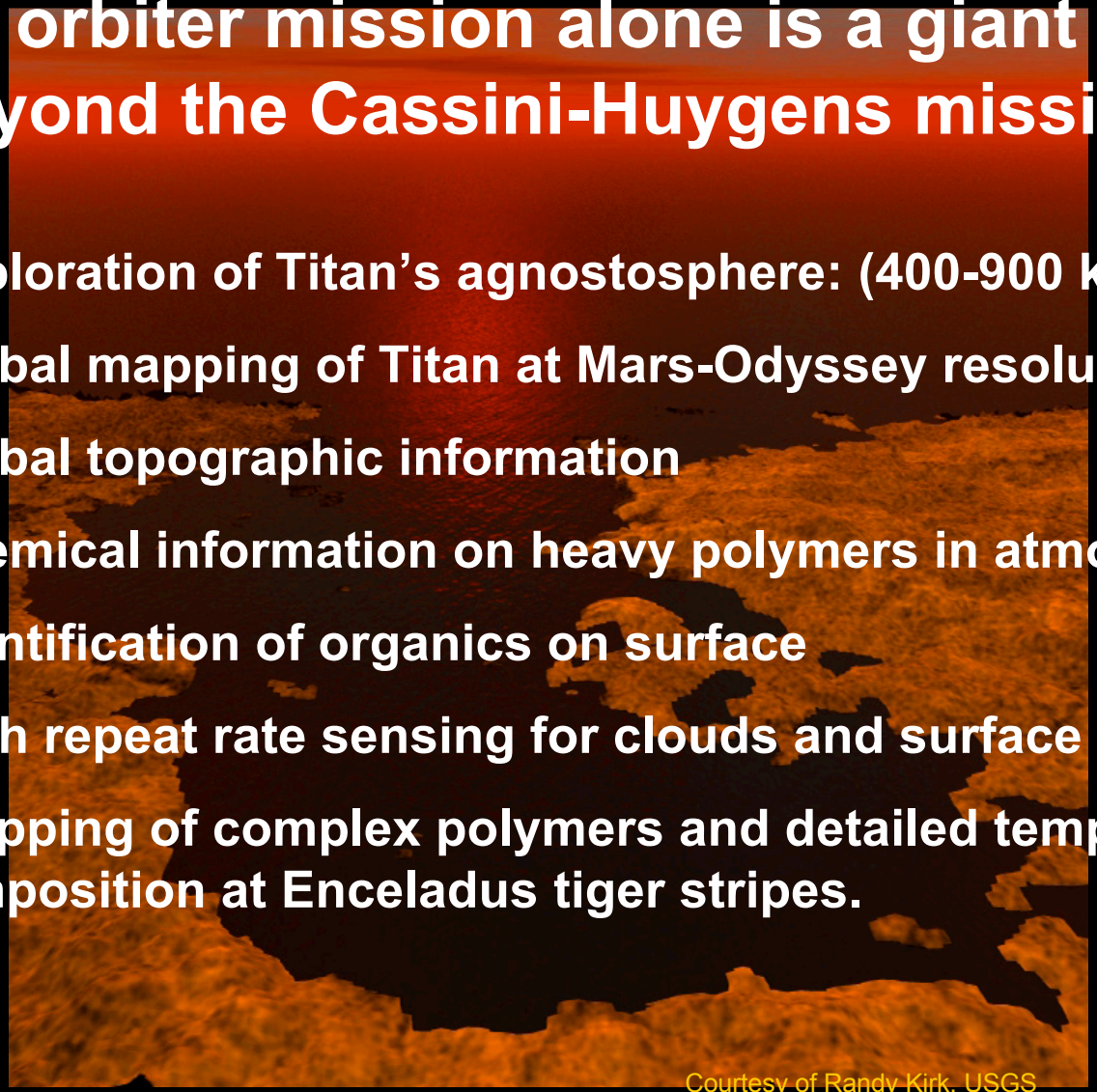
Model Payload

- **HiRIS: surface, atmosphere, interior, Enceladus**
- **TiPRA: surface, interior**
- **PMS: atmosphere, magnetosphere, Enceladus**
- **SMS: atmosphere, magnetosphere, Enceladus**
- **TIRS: atmosphere, surface, Enceladus**
- **MAPP: magnetosphere, interior**
- **RSA: interior, atmosphere**

Payload meets the mass allocation

This orbiter mission alone is a giant leap beyond the Cassini-Huygens mission

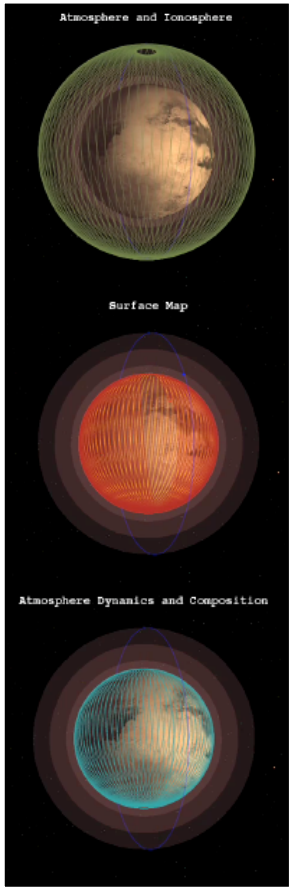
- First exploration of Titan's agnostosphere: (400-900 km)
- First global mapping of Titan at Mars-Odyssey resolution
- First global topographic information
- First chemical information on heavy polymers in atmosphere
- First identification of organics on surface
- First high repeat rate sensing for clouds and surface activity
- First mapping of complex polymers and detailed temperature and composition at Enceladus tiger stripes.



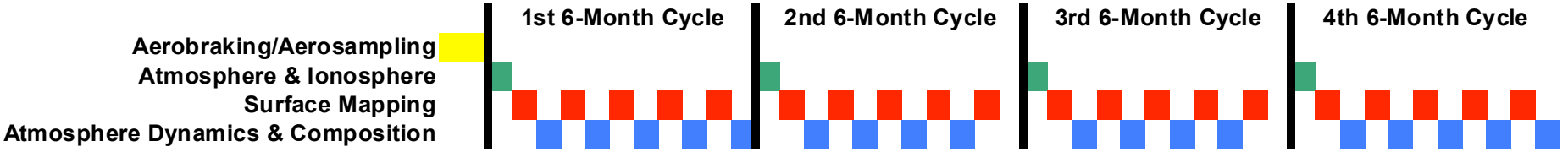
Courtesy of Randy Kirk, USGS

Titan Orbiter Example Science Scenario

- **Three types of science orbits achieve global coverage**
  - Atmosphere & ionosphere: identify and measure ions and neutrals globally for various Sun angles
    - Polymer Mass Spectrometer; Magnetometer and Plasma Package
  - Surface map: global map in up to 4 colors; global altimetry with better than 10-m accuracy; surface spectroscopy
    - High-Resolution Imager and Spectrometer (near IR); Titan Penetrating Radar Altimeter; Magnatometer And Plasma Package
  - Atmosphere dynamics and composition: measure temperatures, composition, and winds, globally
    - Thermal IR Spectrometer; Sub-Millimeter spectral Sounder
- **Maintain each orbit type for one Titan revolution (16 days); reset at 6 month intervals**



Example scenario demonstrates achievement of science objectives



The stay of the Cassini-Huygens mission on the surface of Titan was unfortunately brief; but this moon of Saturn is the locale that is arguably likely to support exotic life.

Limits of Organic Life, National Research Council. 2007